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Efficient encoding of stereo information produces sparser responses to natural binocular images.

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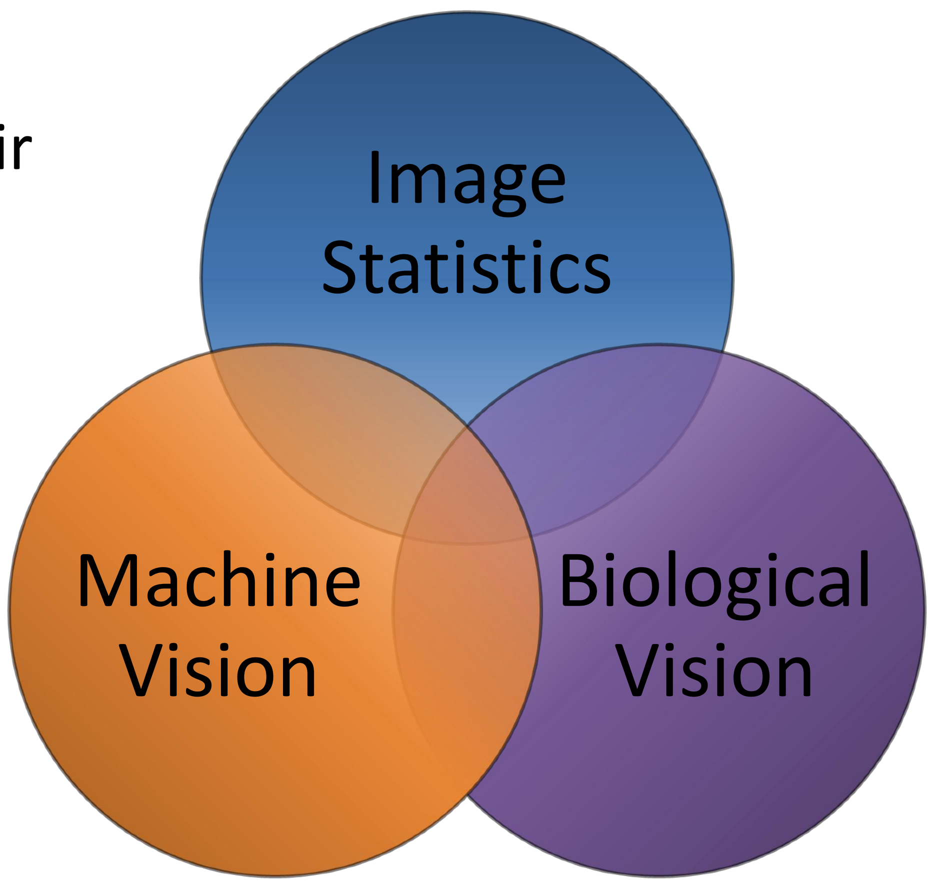
Applications to Biological Vision

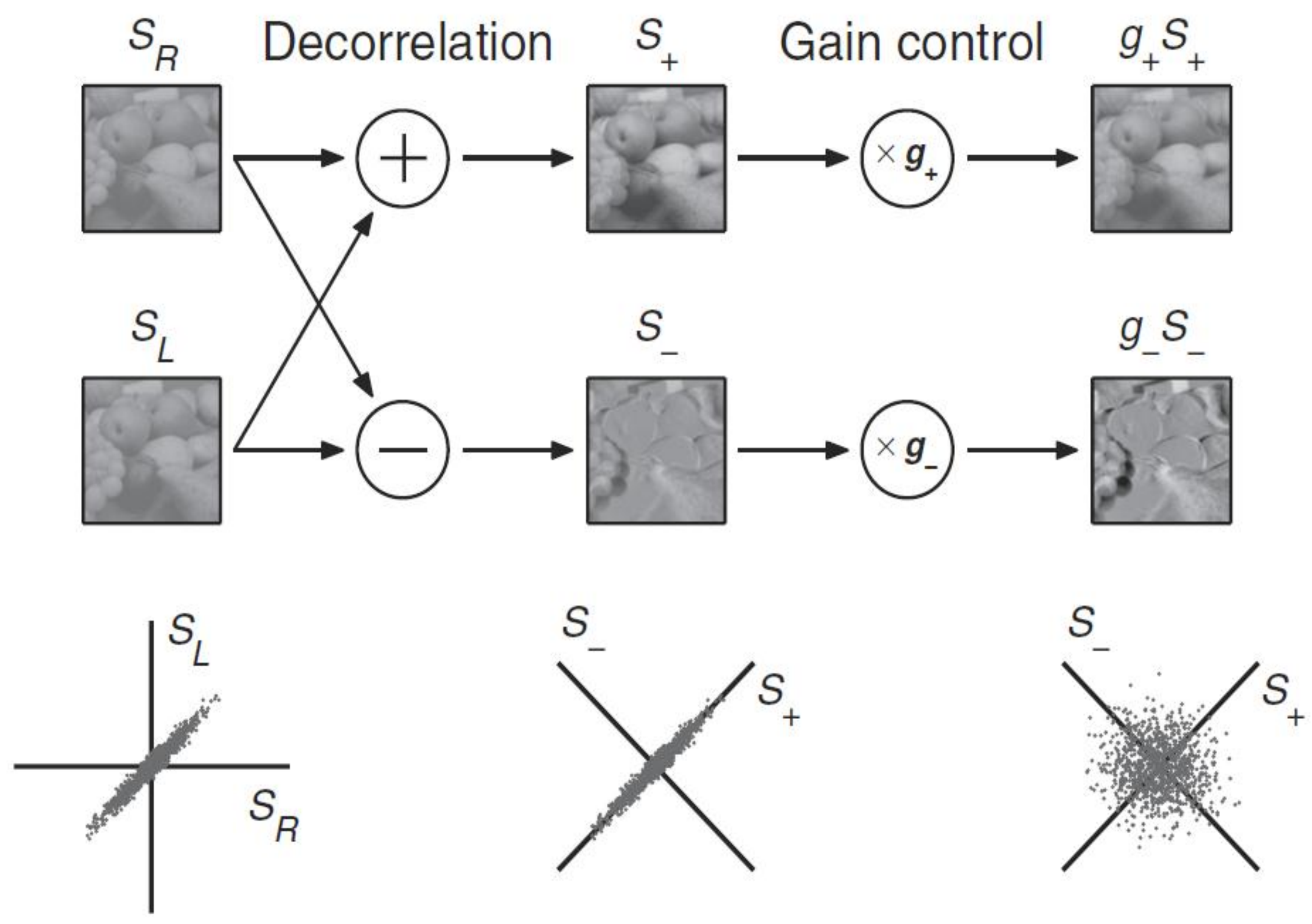
Biological vision adopts efficient representations of *ecologically valid* stimuli based on their statistical structure.

Statistical analysis of natural images provides a powerful tool for understanding psychophysical and physiological results.

Applications to Computer Vision

Develop biologically inspired algorithms for solving the stereo correspondence problem.



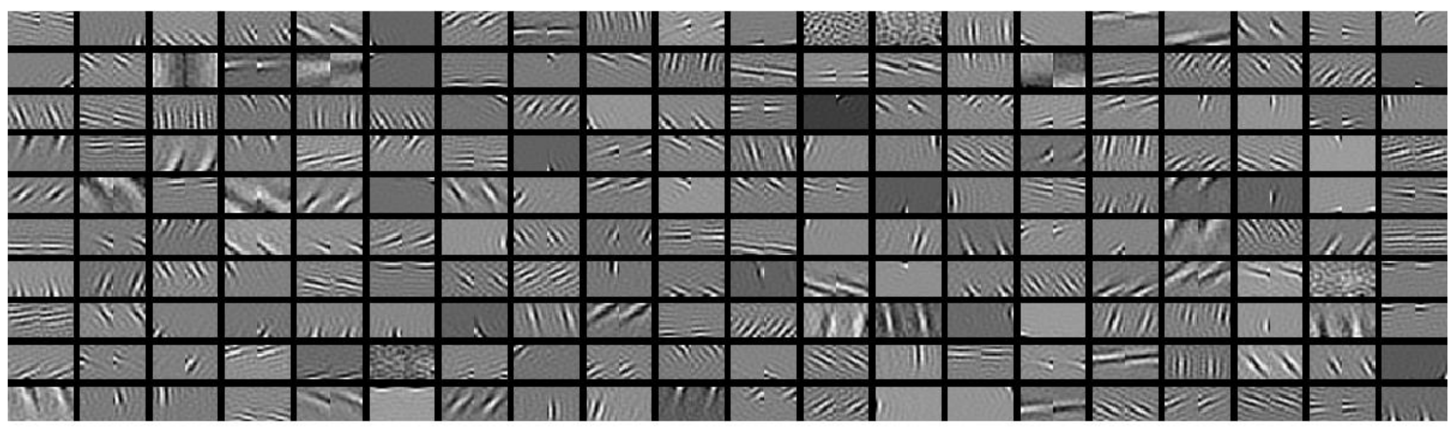


Efficient Coding

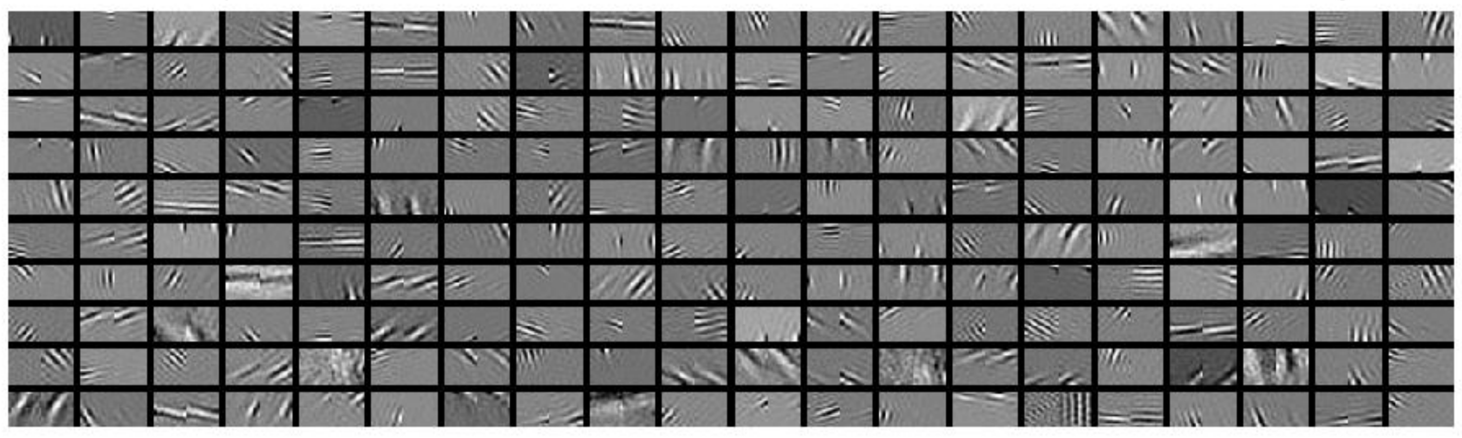
Li and Atick suggested that summation and differencing channels may be employed in binocular vision to de-correlate input signals resulting in a more efficient representation[2].

Psychophysical experimentation performed by May, Zhaoping and Hibbard provided compelling evidence in support of this theory[3].

Results of applying ICA to binocular image patches



ICA on patch from de-correlated binocular images.

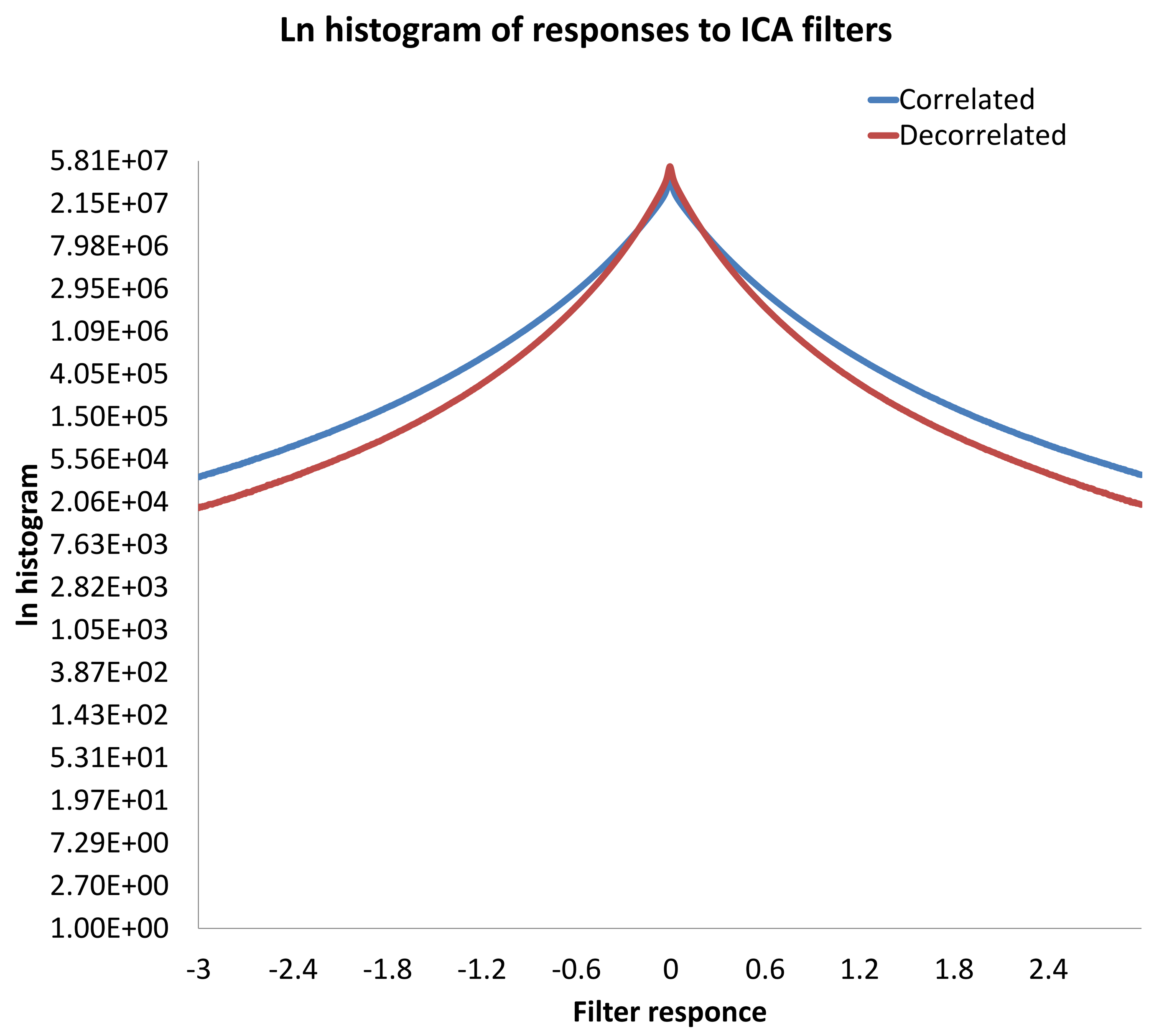


Examples of filters generated by performing ICA on image patches taken from identical locations on pairs of binocular images (top) and the same process performed on images pre-processed using addition/subtraction de-correlation (bottom). The patch pairs are shown as a grid (black borders). The left half of the patch is taken from the left/subtraction channel and the right half of the patch from the right/addition channel.

Sparse Coding

The sparse theory of neural-encoding is inspired by the energy requirements and subsequent firing patterns of biological cells. Most responses will be zero, only a small number of cells responses will have a high magnitude. It was first used by Olshausen & Field [4] to compute, from natural images, filters that mimic responses of part of the V1 visual cortex. Due to a higher level of statistical independence a sparse-coding may result in more efficient binocular disparity and fusion algorithms.

Here we use Independent Components Analysis (ICA) in the manner of Hoyer and Hyvärinen [1] to compute filters on binocular patches taken from natural images. ICA emphasises sparsity by maximising kurtosis.



Sparsity of filter responses to efficient coding.

Provided the Reponses are centred around zero, kurtosis provides a measure of signal sparsity. By convolving the binocular images with filters computed by ICA be can analyse the responses to these filters. We found that binocular signals pre-processed using Li and Atick's addition-subtraction de-correlation method were slightly but significantly more sparse than signals that were de-correlated by PCA alone (a pre-processing stage in ICA).

Kurtosis for the de-correlated input was 11.23 and for un-de-correlated 10.53.

Wilcoxon signed rank test found this difference to be significant. P=7e-170, zval = -27.8.

We conclude that Li and Atick's de-correlation step performed on binocular image inputs results in a more sparse response to ICA trained filters, and therefore more efficient coding of binocular input.

[1] Hoyer P.O. and Hyvärinen. A. "Independent Component Analysis Applied to Feature Extraction from Colour and Stereo Images." *Network: Computation in Neural Systems,* 2000, 11(3):191-210,.
[2] Li Z. and Atick J.J. "Efficient Stereo Coding in the Multiscale Representation" *Network: Computation in Neural Systems,* 1994 pp.1-18
[3] May K.A., Zhaoping L. and Hibbard P. B. "Perceived direction of motion determined by adaptation to static binocular images", *Current Biology*, (2012), 22:28-32
[4] B. A. Olshausen, D. J. Field "Emergence of simple-cell receptive field properties by learning a sparse code for natural images." *Nature*, (1996) Vol. 381, No. 6583, pp. 607-609